flux

a publication of the
national high magnetic field laboratory

RECYCLING
UPDATE!
helium
INFRASTRUCTURE
ENERGY
induction lighting
superconductor
BUDGETING
REPURPOSE
green
LAB
BIG
RESULTS

In This Issue

VOLUME 2: ISSUE 2

FEATURES

ABOUT flux

Flux is a twice-yearly publication dedicated to exploring the research, magnet technology, and science outreach conducted at the National High Magnetic Field Laboratory in Florida. Want to get some extra copies for a classroom or a favorite science buff? Contact Amy Mast at winters@magnet.fsu.edu.

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small STEPS BIG RESULTS: GREENING THE MAGNET LAB

BY AMY MAST

The Magnet Lab is known for doing things big. Big-name scientists use big grants to do big research on some of the world's biggest magnets.

Some things, however, are better small — like trash piles, electric bills and water usage. From small steps such as recycling to hugely ambitious ones such as rethinking the design of research magnets, the lab is working to get the same big scientific results with a smaller environmental footprint. Many of the lab's conservation measures share the added advantage of saving money — another important goal in a research environment where every dollar matters.

Motion sensors replaced traditional light switches in many spaces throughout the lab.

Small steps, electrifying results

The world's most powerful magnets naturally require a lot of, well, power. The lab's superstar 45-tesla hybrid magnet, when running at full field, uses about $27,000 worth of power during a nine-hour work day. The overall power bill at the Tallahassee facility generally runs around $570,000 per month — about 7 percent of Tallahassee's total power capacity. Over the past three years the annual bill has been reduced by about $400,000 a year through a combination of simple measures that, when applied to a facility this size, can really add up.

During this time, the lab:

- Replaced an aging and inefficient vacuum pump with a lower-horsepower, more efficient pump. The old pump cost about $20,000 per year to operate; the new one, a mere $700.
- Replaced old air compressors with higher efficiency models, saving about $20,000 in electricity per year.
- Pulled out extra light bulbs in rooms that were already adequately lit.
- Installed motion sensors on the lighting systems in all offices so that they'll go dark when unoccupied.

Engineering technician Alfie Brown holds one of the lab's new induction lights, installed high over the Ion Cyclotron Resonance lab. Because the lights themselves have tiny magnetic fields of their own, they can only be used in labs with very high ceilings. *Photo by Amy Mast*

- ➤ Lowered the heating set points by two degrees.
- ➤ Replaced the lighting in the lab's Ion Cyclotron Resonance lab with newer, brighter induction lighting that lasts four times as long as conventional lighting.

"A lot of the measures we're putting into place are things we tried before. Maybe it was a little costly at the time, or we got too many complaints and we dropped it," said Facilities Management Director John Kynoch. "But during the past couple of years, gas prices went so high that a lot of people started thinking about energy efficiency in more everyday terms, and revisiting some of those things we'd initially suggested made more sense. People are willing to put up with a small inconvenience here or there if there's a measurable result."

Maintenance and Construction Superintendent Richard Brooks supervised the unloading process when several semi trucks showed up on a muggy summer day to deliver the lab's four new helium tanks. The tanks will make pressurizing, storing and reusing the lab's costly helium supply easier. *Photo by Amy Mast*

Kynoch said that once funding is in place, his group also plans to install water-efficient toilets and lower-wattage (but just as bright) lighting in office space.

Streamlining support infrastructure

The magnets that eat up the bulk of the lab's energy usage have a "big three" of support resources: electricity, water and supercooled liquid helium. Electricity provides power, while water and liquid helium temper the heat created by all that energy. These big three come with some big bills; in addition to that $400,000 monthly electric bill, add in $1.3 million per year in liquid helium.

There's no way around it — the Magnet Lab uses a lot of water, about 250,000 gallons on a typical summer day. About 200,000 gallons of that water evaporates in the lab's cooling tower while the other 50,000 gallons run out of sprinklers and back into the ground. Kynoch says his team is exploring ways to improve that ratio.

As for helium, while there's a helium recycling system in place, capturing and reusing a colorless, odorless gas can be a pretty tricky proposition, one that Kynoch describes as "challenging and expensive." Helium used to keep the magnets cool heats up and boils. The boiled-off gas is captured and piped through a system where it's purified and re-cooled.

Sounds great, but there are three big problems. First, the system that's in place can't keep up with the amount of helium being used in the lab's magnets. Second, the system is full of holes — literally. The pipes that carry helium through the building are made with PVC and for every leak technicians find and repair, Kynoch says, several more spring up. Third, helium is a natural resource, and while it is one of the earth's most plentiful elements, it must be extracted from natural gas fields and then purified. This supply won't last forever, so conserving and reusing the helium the lab buys is the environmentally responsible thing to do.

Kynoch says the lab will eventually purchase a new stainless steel recovery and purification system. With it in place the lab ➔

Recycling bins like this one wait near each of the lab's printing stations and in each office area. Recycling stations for bottles and cans also dot high-traffic areas of the lab.

could go from recovering 30 percent of its used helium all the way up to 80 percent. Do the math, and that $2.5 million needed to update the system starts to make a lot of sense. The system could pay for itself in about two and a half years. Helium storage is already improving, with four new tanks capable of storing the equivalent of 9,812 liters of liquid helium behind the lab, enough to power the lab's biggest superconducting magnet for two months.

The lab's biggest energy monster, however, is the plain old electricity used to ramp the magnets up to their super-strong fields. Last year, DC Program Director Eric Palm was part of a team charged with rethinking how the lab uses energy. Instead of giving magnet users a limited amount of time to spend in the experimental "cells" that house the magnets, the new system allows more flexible time, but puts users on an energy budget. Now, scientists have all the time they need to solve problems or make repairs during an experiment — but they have to watch the bottom line when it comes to energy.

"Many users didn't like the change at first. In the past, we asked people to be energy-conscious, but they weren't truly aware of their contribution to the power bill, and without things being quantified it's hard to really see your own impact," said Palm. "And the numbers were astronomical. Somebody sitting at full field in the hybrid will cost about $3,000 per hour for the energy bill alone."

Palm said because of the energy budget, people are more aware of how much energy they are using.

"Like anybody with a budget, you're really squeezing at the end of the month, trying to make everything fit," he said. "People are really thinking ahead of time and mapping out what they want to do, and it really has made us partners in saving energy."

The amount of energy used in a magnet is proportional to the magnetic field squared, meaning that conducting an experiment at 20 tesla uses only a fourth as much energy as the same magnet at 40 tesla. With that in mind, researchers are also being encouraged to collect data with the minimum magnetic field needed to get the results they're after. "Around here, money-saving and being green can be the same thing, which is great. This kind of approach saves us a lot of money and energy, which we can use for other things," said Palm.

Building greener magnets

Another way to conduct leaner, greener research is to rethink the way magnets themselves are built. The Series Connected Hybrid, currently under development by the Magnet Lab, is one of two ambitious attempts in that direction.

A key advantage of the new magnet, which is a hybrid of a resistive and a superconducting magnet, is that it will use one-third less power than traditional all-resistive magnets. That means experiments can be performed at lower cost and for longer time frames than would be the case using existing all-resistive magnets. Resistive magnets require both electricity and cooled water while being used; superconducting magnets require little or no electrical power to run once they are brought up to full field so long as they are cooled to ultra low temperatures. Eventually, multiple numbers of such hybrid systems will increase the number of experiments that can be carried out at the lab each year.

Even more ambitious are plans to build a 32 tesla all-superconducting magnet. New materials have been evaluated and tested that far exceed the performance of niobium, the material that has been used to build most superconducting magnets up to this point. Niobium-based superconducting magnets are limited to a field of about 23.5 tesla.

"The average cost for a resistive magnet is $774 an hour, and the lab's 20-tesla superconducting magnets are $18 an hour," said Tim Murphy, director of the lab's Millikelvin facility. "Measurements that require sitting at high fields for long periods of time would greatly benefit from a 32 tesla superconducting magnet, since they could sit at high fields for days without incurring huge electrical costs."

Recycling on a grand scale

There are almost as many different ways of recycling materials the Magnet Lab as there are materials. The lab's recycling program, in place for the past three years, now gives new life to about 65 percent of all trash leaving the lab.

It takes a lot of packaging to safely deliver scientific and other equipment to the lab: 120 pounds of cardboard are recycled by the lab each week. Packing peanuts from deliveries are picked up by UPS, which reuses them in new packages. Stations for regular office paper, plastic, glass and aluminum are stationed throughout the building, but the lab also recycles difficult-to-dispose-of items such as scientific equipment and computers. Even wood from shipping pallets is picked up by Florida State University and ground into the mulch that surrounds campus buildings.

When contracting upgrade and replacement projects on the lab's infrastructure, Facilities Engineer Sean Coyne says that the lab generally specifies that all recyclable waste materials from those projects is disposed of properly. A recent update of the fire alarm system yielded four tons of recyclable conduit.

"We recycle the waste metal from the welding shop and the machine shop as well. Usually it's lots of small stuff, but we've recycled as much as eight tons at a time," said Coyne.

Taking a long view

There's no way around the fact that the lab uses a lot of energy, but in such a big place, small changes like the ones described here really add up over time. Big steps — such as the 32 tesla all-superconducting magnet — may take longer, but when they're successful, they'll mark a permanent departure from the old standards of energy use. And who knows? Maybe some of the material magnet technicians use during assembly of the new magnets will be making its second trip to the Magnet Lab. ■

Eureka Moments

How four people discovered science

BY KRISTEN COYNE

We all know the common stereotype of a scientist: the white-coated, bespectacled genius, in desperate need of a decent haircut, experiencing a flash of insight in his lab. In this mental cartoon, the scientist is positioned below a light bulb and a text bubble with the word "Eureka!" (Greek for "I have found it!") inside.

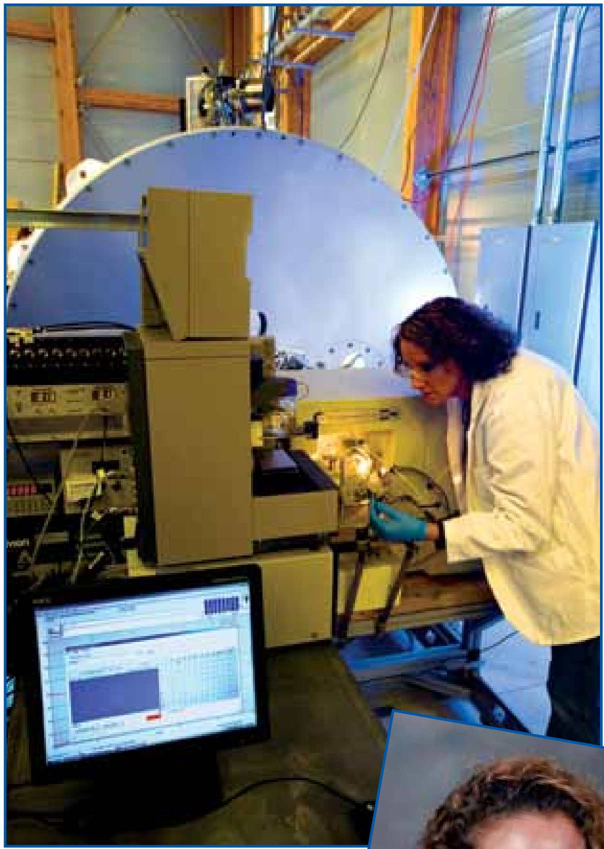
Science is full of eureka lore, from Archimedes' sudden understanding of how to determine the purity of gold (the original eureka moment, in fact) to Thomas Edison's cry, "Come quickly, Watson, I need you," to Einstein's rapid trajectory from a Swiss clock tower and street car to $E=mc^2$.

We set out to collect such "eureka moments" among some of the scientists at the Mag Lab. We wanted to know when they discovered the wonder of science and realized they would pursue it for a living. We discovered that our hypothesis was a bit off: The path of a future scientist reveals itself not so much in a sudden flash, but in a sequence of events.

On these pages four Mag Lab staffers, from lab assistant to scholar scientist, describe how they came to be where they are today.

Math stood in the way of chemistry career

Amy McKenna, Ph.D., Ion Cyclotron Resonance Program



Amy McKenna, who recently defended her dissertation, conquered and even learned to enjoy math along the way. *Photo by Ray Stanyard*

Amy McKenna, shown here in her senior picture, says math stood in the way of her career ambitions.

I always enjoyed school, but I struggled with math, even in elementary school. I tried really hard and did my best, but never quite excelled at math as I did at other subjects. As a headstrong teenager, I refused to accept "that some people just are not good at math," as my parents would say. Academic rock bottom came in high school when I got a D in algebra. I was furious at myself and directed my anger at my terrible algebra teacher. I blamed him for my inability to excel, refusing to believe that the same studying approach that earned me As in other courses was insufficient for math. I scraped through math in high school, barely above average.

When my father died after my freshman year of college, it took me six years to find my way back to school. At 25, I wanted a worthwhile degree that was going to mean something and be a challenge. I fell in love with chemistry because it was methodical, logical and followed a defined sequence. I liked that it was based on data rather than opinion. When I saw the courses required for a degree in chemistry, I knew I needed to tackle upper-level math: not just complete the courses, but actually understand the material. I went to the first day of calculus with a resolve that I would understand the material and enjoy it.

It worked! The biggest surprise was that I actually enjoyed it. I remember going home from my bartending job on Friday nights, excited about working on differential equations. Now that I had a handle on the math fundamentals, I could focus on chemistry. Analytical chemistry found me. My first professor at the University of Tampa took me under his wing and told me, "You will go to graduate school." I was married by then with a baby boy to take care of, and had not even considered an advanced degree. But my husband pushed me to apply to schools and we settled on Florida State University.

In retrospect, I am amazed to be a Ph.D. in analytical chemistry. After eight years of study — all while raising three children — it seems like a huge mountain I have climbed. But I never looked at the big picture while I was going through it. I focused on the immediate future, telling myself, "Just get through this semester, then you can quit if you still want to." I soon realized it wasn't so hard, after all. It was no longer work; it was what I wanted to be doing. ➔

Magnets fueled passion for science

Dominic Maldonado, lab assistant

Now in his senior year of college, Dominic Maldonado is an assistant in the lab's instrumentation division *Photo by Kristen Coyne*

The young Maldonado was a 7th grader living in Hawaii when he first developed his fascination with magnetism.

I remember my first science-fair project. I was in 7th grade, living in Hawaii. After flipping through my science book for ideas, I chose to experiment with electromagnets. The components seemed simple enough — magnets, power source and wiring — and the concept of amplifying an unseen electromagnetic force intrigued me. Some days later, after picking up a stack of magnets, a 6-volt battery, booster cables and tri-fold poster board from the hardware store, I set off to explore uncharted territory at the kitchen counter.

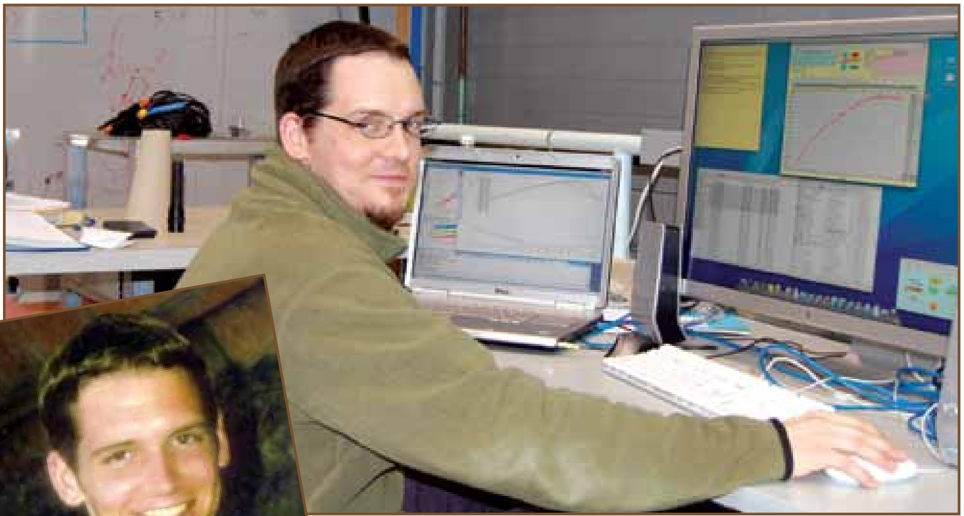
The magnets I bought had holes drilled through the middle, so I threaded my pencil through them, aligning them north to north, south to south, such that the repulsion stretched the entire length of the pencil. With that I was hooked; I moved from the kitchen — homework territory — to my bedroom, where I always escaped to play. After all, I was no longer doing schoolwork; I was having fun. I experimented with various objects — toys, loose change, paper clips — to see how they would interact with the magnets. I was fascinated by this unseen force, more powerful than gravity, which had suddenly become visible to me. I started putting the puzzle pieces together in my head.

I became so obsessed with the magnets' properties and behavior that I forgot I was doing a science project, let alone one that was due in a couple days. I prepared my poster board and presentation so quickly, in fact, that I forgot to test my experiment with the battery, which turned out to be a dud. Despite the technical difficulties, I scored well at the fair. But I wasn't concerned with the project so much as the new hobby tickling the back of my mind.

I'm now a senior at Florida State University. My majors are international affairs and creative writing, but science continues to tickle my mind. I read about it, notice it all around me. That's what drew me to the Mag Lab. As a part-time lab assistant, I get to work with lasers, optoelectronics and ferrofluids while expanding my knowledge of electromagnetism by attending seminars at the lab. Science also finds its way into other things I do: I write science fiction and choreograph routines — inspired by atomic motion, quantum electrodynamics and superluminal theories of space-time — for the motorbike crew I manage and perform in.

Eureka? More like a gradual dawning

David Graf, postdoctoral associate, Condensed Matter Science



Now in his 10th year of doing research, Graf often uses the lab's world-record 45-tesla hybrid magnet. *Photo by Kristen Coyne*

Graf in graduate school. He was the lab's first Crow postdoctoral associate, an honor named for the lab's first director, the late Jack Crow.

I'm sure some people have a real discovery moment, when they sit down and have a light bulb go off over their heads about science. But for me it took a long, long time to go from, "Hey, maybe I'll try science," to, "I really like doing research."

In high school and as an undergraduate physics major at Buffalo State College, I spent summers landscaping. I even considered it as a career, and at one point offered to buy out my boss (he wasn't interested). Then one year my adviser asked, "Why don't you come and work for me for the summer?" I thought, "Sure, why not?"

That summer I saw graduate students and postdocs work long hours and speak passionately about topics that would put most people to sleep. I didn't get it: I still lacked the skills it took to fill a 12-hour workday. Physics was interesting enough that I ultimately decided to go to graduate school, but I didn't know if I would ever be as invested in research as the scientists around me.

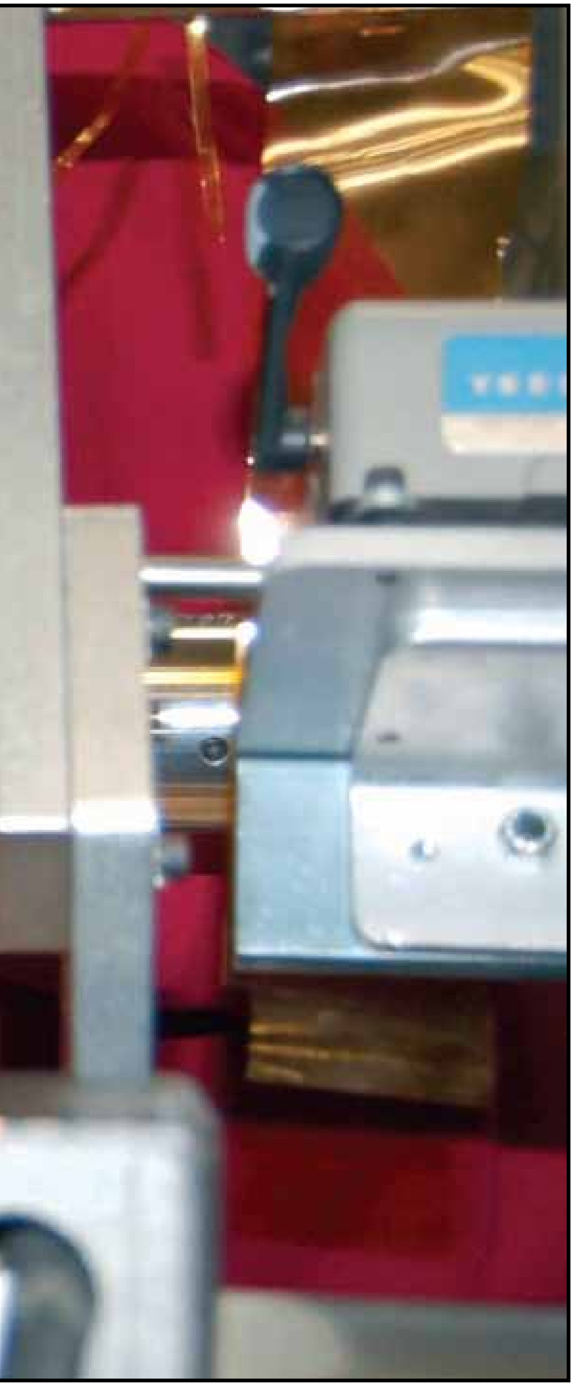
In the beginning of my research assistantship, if I arrived early, stayed late or worked during the weekend, it was partially because I thought my adviser expected me to be there. I needed lots of specific instructions, because no one knows what they're doing right off the bat. You know you're supposed to read papers, but which papers? You know you're supposed to fix things, but which things, and how do you fix them? But as you learn what you're doing, you become self-motivated. You can come in to work and prepare a mental to-do list: "I need to read this paper, repair that probe, prepare figures for a manuscript and begin my next measurement."

After several years I started to work on my research without my adviser looking over my shoulder. Occasionally, I even came up with my own ideas of how to improve the experiment and results. I began to read papers because I was searching for answers, not because I knew my adviser would ask me if I had. I learned to focus, and I started to become territorial. That's when you start to feel like a scientist, because you feel like, "This is my project, I need to understand the science behind this research."

Now I have been doing research for almost a decade. I see new graduate students in the lab every summer looking a little bit lost. I have a theory that you can tell what year a graduate student is in by how slowly they walk in the hallway. Early students just need to be taught new skills and be pointed in the right direction, while students in their last year usually look like they are racing towards a finish line. ➔

A scientist from day one

Denis Markiewicz, scholar/scientist, Magnet Science & Technology



Children learn early from those around them, and from my youngest days I was taught the wonder and awe of the natural world. Simple things like the beauty of flowers, a rainbow, the Milky Way, the action of waves at the beach, were valued experiences when shared with a loving adult. I remember gathering in the backyard with family and neighbors one night to watch a lunar eclipse. This atmosphere was a most important factor in forming my interests, and from a very early age my general orientation toward science was set.

Somewhat later, even as a boy from a family of modest means living in a small town, I had the opportunity to see the workings of science on a large scale. During World War II my father had been a radio operator aboard a Navy destroyer. He later taught himself how to repair TVs, which were just becoming widely available, and he made a business out of it. So we had a set several years earlier than would otherwise have been the case. In the afternoons, I selected the stations. After the war there were many documentaries on the development of the atomic bomb, and I learned the story of Oppenheimer, Trinity, the Enola Gay, Hiroshima and Nagasaki. Although the events were terrible, I could see the importance of science, and that science could be a means to having a life. "Scientists go to work and get paid to do science," I thought. And for me the choice has been good. Science offers the opportunity to work hard and the satisfaction of accomplishment.

From the time he was a little boy, Denis Markiewicz was taught to appreciate the natural world.

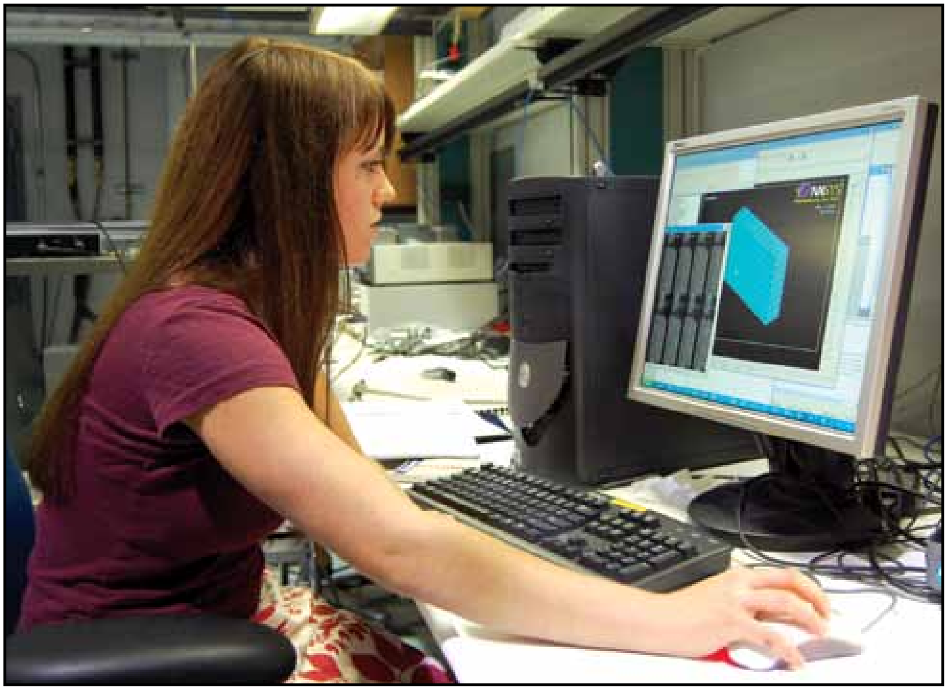
Markiewicz says he was a scientist from day one, and he is now one of the world's premier magnet scientists.

One Magnetic Summer

BY AMY MAST

Every year, as summer heats up and college students pack up and head home, a select group of students trickles *into* the Magnet Lab from all over the country and gets to work. They're the lab's Research Experiences for Undergraduates participants— students who are serious about exploring science as a career. They come from big name schools, small-town colleges and many different backgrounds. For many of them, the Magnet Lab is their first experience in a large lab environment. At the close of their eight-week experience, each student presents a project prepared under the supervision of a staff scientist.

This year, two students, Jonathan Padelford of Columbus State University and Kayla Crosbie of the University of Colorado, kept weekly blogs on the Magnet Lab's Web site about their experience. Below are some highlights.



Kayla Crosbie constructs a model of her sample using the ANSYS modeling program. *Photo by Amy Mast*

Kayla's story:

Week 1: I knew when I was a junior in high school that I wanted to be a physicist for sure. I had liked science for a while, but physics especially was the most interesting conceptually for me. Double-majoring in math seemed like a good idea if I decide to be a theoretical physicist, but I also just really love math.

The Magnet Lab is fantastic. In some ways the lab has been a lot like what I expected — this huge place with a ton of lab equipment and a ton of people from different fields. I'm in a little apartment-style dorm that is shared with seven students from out of state, so I am getting to know all of them really well.

Week 3: I've been really happy with the level of work I've been getting to do. I feel like it's pretty difficult, but then it gets easier once I start putting what I read about into action in the lab and there's immediately something new to learn.

Week 8: I think two of the most important things I've learned this summer are learning to complete a project on a set schedule and — I guess I'd call it goal-oriented reading. My mentor would give me a huge book to read and I had to learn to get the information I needed out of it instead of going over every word. I've learned a lot about working efficiently and working smart. One thing is for sure — regular homework is going to seem really easy.

I also really liked learning a little bit more of how to separate my social life from my physics life. I liked the rule at lunch here that there was no talking about work. It really helped clear my head and enforce that separation a little bit. Life is more enjoyable when you're not always in that weird middle zone.

Johnathan Padelford prepares a mixture for an experiment. *Photo by Amy Mast*

Jonathan's story:

Week 3: I am learning something new from my mentor pretty much every day. I consult him before anybody, and we probably talk 30 minutes to an hour a day — he has helped with the analysis and figuring out what was going on in my samples as well as other things. He has a direction that he wants me to go in and he's starting to ask me what I think about it, and if there's anything I might do differently.

Week 4: The lab part of the environment — actually doing the experiments and dealing with the materials — is definitely my favorite part. Sometimes it's a little hectic and there's been a couple times I wanted to pull my hair out, especially when I walked in and saw that our sample was ruined. But it's pretty cool to see what all these scientists go through on a day-to-day basis.

Week 5: You are going to have failures and you are going to have to be equipped to get over that. Some of those failures are because of little mistakes you make and some of them are things you can't help, like the machine or the power supply not operating correctly. Learning the patience to get through those kinds of moments and accepting them as part of research is probably one of the biggest lessons I'm going to take back to school.

Week 7: It's kind of messed up to be part of all this progress and know I have to leave next week. If I could stay longer I definitely would. This has been awesome, and I'm glad I have a couple years left of undergraduate work so I can do a couple more programs like this. ■

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For more information about the Magnet Lab's REU program, contact Jose Sanchez at sanchez@magnet.fsu.edu or (850) 645-0033.

EMR Director Stephen Hill

BY AMY MAST

Though Stephen Hill was only recently hired to lead the Magnet Lab's Electron Magnetic Resonance (EMR) program, his relationship with the place dates back to the lab's earliest days. Below, Hill, originally from outside Oxford, England, talks about the path to a career in science and how he ended up at the helm of a program that had helped to shape his own career.


Steve Hill in front of the lab's 45 Tesla hybrid magnet *Photo by Ryals Lee*

How did your relationship with science begin?

I grew up six miles outside of Oxford. My village would come to be the place where **Oxford Instruments**, a company that has such an influence here at the Magnet Lab, started out.

At that time, the English educational system narrowed your focus of study at a very early age. I guess I was drawn to math and science long before I thought about a career path very seriously. For one, I wasn't bad at science, and my father was a chemistry lecturer, so I was exposed to conversations about science from an early age. When I was a kid he would set up the kind of cool experiments you often see here at the Magnet Lab Open House for my birthday parties.

I went to a very unusual elementary school where the curriculum essentially allowed the students do what they wanted for a large part of the day. I think this system suited my natural curiosity, but maybe it was not ideal for everyone. Once I got to secondary school I did well in the sciences, and the system was structured so that students moved into areas where they showed interest and aptitude. Probably by the time I was 14 I had a structured course load doing mainly math and science and almost no arts or languages. By the time I was 16, this was reduced it to just math, physics and chemistry. All of my science teachers were absolutely fantastic.

So by the time you got to college, you knew you would be a scientist?

At university, there were no electives -- I studied only physics. There are a lot of similarities between the U.S. and the U.K., but education is very different. It has its advantages because I was pretty much done with my Ph.D. by the age of 25, but I'll be honest and say I don't think I had the most well-rounded education.

I was very comfortable on the science track and I never had any doubts about following this path. I think the only choice I needed to make during my education was between chemistry and physics. My father was a chemist but my parents never pushed me in any specific direction except to encourage me to pursue the things I was curious about. I was pretty self-motivated and I think they understood that this was all I needed.

I actually struggled initially with chemistry, while physics came surprisingly naturally, so it was more natural to do something I was good at. But chemistry has actually crept back into my life as my career has progressed.

It really was amazing to me when I came to the States to see how the university system operates here. We had just one week of exams after three years of study, with no second tries. Nobody checked to see if we learned the material in a particular course. The first few years at university, I'm not sure if I was a terribly good student. I had the luxury of enjoying myself a bit too much — at least for the first year and a half. I had a fantastic time playing several sports and socializing. I buckled down after that.

So did you always plan on getting your doctorate?

Obviously, my father had a Ph.D., so I knew it was an option down the road. In the later years of my undergraduate career I got an internship to work summers with a company. It was nice to be doing something different, but when they offered me a job at the end, I didn't accept it.

In my final year of undergrad we had to narrow down even more to a subfield of physics. My tutor happened to be **John Singleton**, who is, of course, now a part of the Mag Lab. He was at Oxford at the time, and once a week we would meet and I would learn **condensed matter physics** from him. I remember John being very serious and very tough, but extremely good and very clear at what he was teaching. Through these tutorials and self learning I gained probably 90 percent of the knowledge that I took away from undergrad. John was extraordinarily hardworking, and I suppose in some sense a bit intimidating -- probably how my students look at me nowadays.

By the end of my degree he offered me a spot as his graduate student, and we just continued without a break.

I think that my relationship with my grad students is similar to mine with John. I try to push them to do their best. With John, he never had to say anything, but you knew that he expected a lot of you.

What happened once your doctorate was complete?

My research for my Ph.D. was heavily rooted in high magnetic field research and I was using magnets at the Nijmegen Magnet Lab in the Netherlands. I also attended conferences relevant to high magnetic fields. I got to meet **Jim Brooks** *[currently the director of the Mag Lab's Condensed Matter Science- Experimental group]* at a conference in Korea in my last year, and he offered me a **postdoc**. It just fell into my lap, and it sounded very exciting. I had no plans to move to the U.S., and I had never been to Tallahassee, but I came here in 1995 and loved it, and I spent two and a half years here with Brooks.

That would have been just after lab opened?

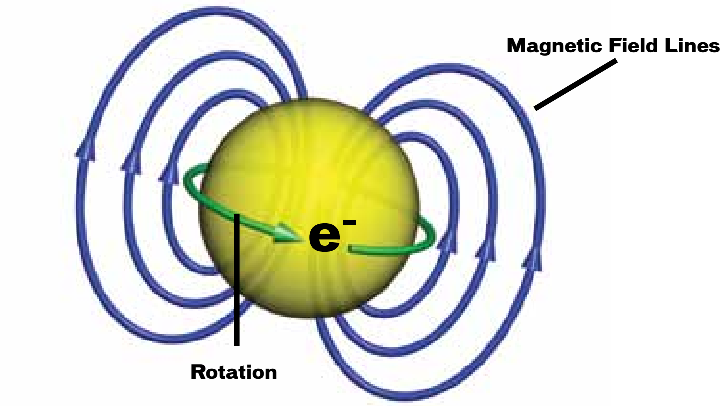
I was probably in with the first group of postdocs who got to be here with the place up and running. Those who came here at that time all ended up doing well. There was so much more space back then.

The biggest thing for me was the fact that even though there was already a **user** community, it was fairly small, so getting magnet time was really easy. We'd constantly get emails saying that such-and-such a

➔

KEY TERMS:

- ***Oxford Instruments:*** *An England-based company that is a major supplier of, among many other scientific products, research magnets.*
- ***John Singleton:*** *Singleton is a staff member and Los Alamos National Labs Fellow at the Magnet Lab's Pulsed Field Facility in Los Alamos, New Mexico, and a longtime member of the Magnet Lab community.*
- ***Condensed Matter Physics:*** *The exploration of the properties of solid matter.*
- ***Jim Brooks:*** *Brooks is the director of the Magnet Lab's Condensed Matter Physics-Experimental group and a longtime member of the Magnet Lab community.*
- ***Postdoc:*** *Often a scientist's first full-time position after receiving a doctorate, postdocs work in the lab of a senior researcher. Some postdocs go on to their own faculty positions and others become full-time researchers.*
- ***User:*** *A scientist who visits the lab to conduct research. Providing space, time for magnet experiments, and equipment for user science is at the core of the Mag Lab's mission.*



Electrons, which are like tiny magnets, are the targets of EMR researchers.

magnet was available, does anyone want it. The mentality in Brooks' group was that if any magnet time was available, we should be using it. I can easily imagine that somebody in his group was using a magnet close to half the time. Now we are lucky to get magnet time for a few weeks out of a year.

No lab can suddenly go from no users to a saturated program of users overnight. We were lucky to be here at that time. We were just churning out phenomenal data, and the magnets were bigger and better than anything that had come before by a significant margin in terms of field. We were looking at lots of things for the first time and I was able to publish a lot of what I found.

Where did you decide to go next?

I was only about 27 and I had done my two-year postdoc here. Brooks suggested that it would be a good idea for me to start applying for faculty positions. It was possibly a bit early in the game. I'd published a fair amount, but a lot of things weren't in print yet.

I got an offer from Montana State University and that was the one time that I wasn't completely sure what to do. This was across the country, a small school, and I didn't know much about the physics there. It turned out that they had great physics. I decided to go; Brooks and also Bob Schrieffer convinced me that I was much better off taking this opportunity because I would have a chance to show what I could do on my own. So I went, and it worked out really well.

EMR

About Electron Magnetic Resonance Science

EMR is the study of how electrons behave in molecules and solid matter. In an atom, electrons have a negative charge, and when a charged object spins, it produces magnetism. In other words, a spinning electron behaves like a tiny magnet. Indeed, this is the origin of magnetism, with the electron representing the fundamental magnetic particle. EMR scientists can study electrons, among other reasons, to learn about the properties of magnetism itself. This is of huge technological importance, given the significant role magnets play in our everyday lives, such as in electric motors and the memory in our computer hard drives.

EMR is one of the most interdisciplinary fields in the Magnet Lab, with areas of study in everything from condensed matter physics to biology and chemistry.

Montana was a beautiful place. We lived in the middle of a valley surrounded by mountains. The scenery was just beautiful and there was, of course, a lot of skiing. But it was remote, and certainly in my area of physics it was a little isolated. My wife is from Florida, and I think we felt a bit isolated there. I started thinking about trying to come back. Then, in 2001, a position became available at UF and we had the chance to move back to Florida.

And then you stayed at University of Florida until this year?

I had no intention of leaving UF, but the opportunity came up to lead the EMR group here. I've been involved in this program, for quite some time. Moving was so easy relationship-wise, because I knew almost everyone. There were obviously new people, but I had been coming back to do work here the whole time anyway, and many of the people from my early days as a postdoc had either returned or never left. It has definitely felt like a homecoming. ■

Indispensible ‘dewars’ keep the lab running smoothly

BY KRISTEN COYNE

If you visit the Mag Lab, you may see a scientist wheeling a stainless steel cylinder down the hall about as big as the scientist herself.

That’s called a dewar, a container used for transporting very cold liquids across our sprawling lab from point A to point B. We use a lot of cold liquids here, specifically liquid nitrogen and liquid helium. Called cryogens, these liquids help us keep superconducting magnets very cold (they don’t work unless they’re at about -451 degrees Fahrenheit). For certain experiments, cryogens are also used to keep samples and tools cold.

A dewar is basically a super duper Thermos. Stuff on the inside stays cold thanks to a vacuum jacket and layers of insulation. The Mag Lab maintains a fleet of 44 100-liter, 250-liter and 500-liter dewars. Scientists collect them from our cryogen stations and wheel them to their experiments. We make our own liquid helium at the lab, transforming it from the gas state in which it is delivered to us by slowly and carefully lowering its temperature. We try to recycle as much of it as we can, because liquid helium costs between $4 and $5 a liter. (Liquid nitrogen, not as rare or hard to make as liquid helium, isn’t as costly.) Not including the cryogens consumed by our world-record hybrid magnet (which is hooked up directly to our helium liquefier), we distribute 7,000 to 8,000 liters of liquid helium a week here via dewars.

Scientists and technicians must use this stuff with care. If the temperature inside a dewar gets high enough for the helium or nitrogen to turn back into a gas, there could be trouble. A liter of liquid helium or nitrogen will boil off into *700* liters of gas; the pressure from such a boil-off could cause the container to burst. The gasses themselves are harmless, neither flammable nor explosive. In fact, we use helium to fill party balloons and breathe in more nitrogen than oxygen with every breath. But if a dewar bursts in a closed space, the escaping gas could displace enough oxygen to cause potentially fatal Oxygen Deficiency Syndrome in anyone present. Fortunately, no dewar has ever erupted at the lab — where safety comes first! ■

This looks like a giant Thermos, and in a sense it is. Dewars are used daily at the Magnet Lab to transport very cold liquids and to make sure they stay cold.

Mag Lab mentors tomorrow's scientists

BY SUSAN RAY

While there aren't any formal classrooms at the National High Magnetic Field Laboratory, school is always in session. Students make up a quarter of the lab's staff, and about 30 percent of those students are undergraduates. The Mag Lab at The Florida State University offers the rare opportunity for undergraduates — as young as freshmen — to work in a national research setting.

Students at the Mag Lab don't sit behind a desk and do Internet research; they are active members of their mentors' research groups. The experience often helps the students narrow down their career choices, and positions them for summer research experiences at other universities and national labs. Some become co-authors on papers published in leading scientific journals.

Several Magnet Lab-affiliated undergraduates recently received top honors for the quality of their Magnet Lab research.

The lab-sponsored engineering team improved the connection between the transfer line and the probe dewar, shown here, an accomplishment that will benefit the Mag Lab's NMR user program.

Best project winners, from left, are Jason Kitchen, Rebecca Altman, Jessica Vanterpool and Zac Stevenson

Undergrads snare best project

Undergraduates sponsored by the Mag Lab's Nuclear Magnetic Resonance facility tied for best project in the 2008-2009 FAMU-FSU College of Mechanical Engineering Capstone program, a year-long course focused on produced realization processes with real-world engineering practice issues.

The team — composed of Rebecca Altman, Jason Kitchen, Zac Stevenson and Jessica Vanterpool — developed a method of maintaining the required temperature of a sample for the duration of an experiment in the lab's flagship 900 MHz magnet.

"This was my first experience with the Capstone program for undergraduate projects," said the Mag Lab's Bill Brey, who together with Peter Gor'kov sponsored the project. "I was very pleased to work with such a bright and capable group of students. Their project makes a meaningful contribution to our user program, improving sample temperature stability in the 900 MHz ultra wide bore magnet."

For more information about the project, visit: www.eng.fsu.edu/ME_senior_design/2009/team2/.

Physics poster first rate

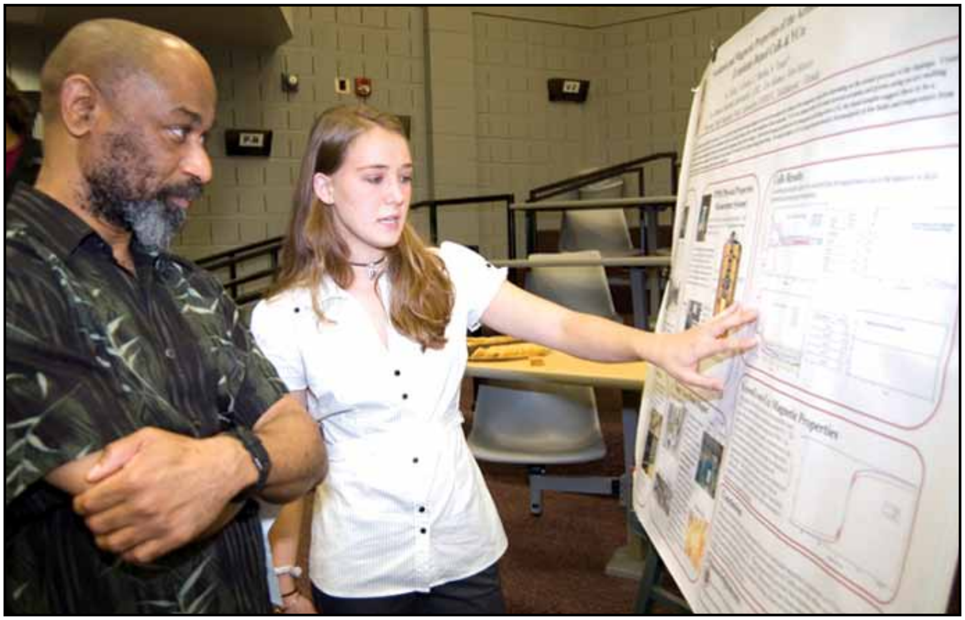
Kristen Collar took first place in the Physics Department's undergraduate poster symposium at FSU, for which she received the Lannutti Award for Undergraduate Research and $750. The award is named for Joseph E. Lannutti, who was a pioneering professor of physics at FSU.

Kristen, who will be a junior in the fall, first came to the Magnet Lab as a freshman through FSU's Women in Math, Science and Engineering (WIMSE) program (page 22). She conducts research with physicist Stan Tozer on the flux growth of crystals and their characterization, an effort funded by U.S. Department of Energy/National Nuclear Security Administration.

"Kristen has been a real asset to our studies on the actinides and related materials," said Tozer. "We have thrown all variety of assignments her way and she has taken them all on with equal verve. With any luck, we will be able to steer her to a career in physics, as she shows real promise as a crystal grower."

At the end of her first year at FSU, Kristen applied for an Undergraduate Research and Creative Endeavors (URACE) Scholarship and received a $1,000 award, and also was accepted to the Mag Lab's Research Experiences for Undergraduates (REU) program at the lab's Los Alamos branch in New Mexico. While there she co-authored a paper that has been published in a respected physics journal.

This summer, she participated in The Center for Compact and Efficient Fluid Power REU program at the University of Illinois.



Undergraduate Kristen Collar shows her award-winning post to FSU physics professor Winston Roberts.

LEARN MORE

➤ *For more information about research opportunities at the Magnet Lab, visit www.magnet.fsu.edu/education and search for "for graduate students."*

Student recognized for outstanding research

Alison Pawlicki received the Lynn Shannon Proctor Fellowship for outstanding research by a student in a group that is underrepresented in the field of physics. The award is given in honor of Ms. Proctor, who was majoring in physics at the time of her death. Alison was also inducted into the Sigma Pi Sigma honor society and took second place in the physics department's undergraduate poster symposium.

Alison, a junior, works with physics professor and Magnet Lab experimentalist Chris Wiebe on the synthesis of new magnetic oxides. This summer, worked on recently discovered "pnictide" superconductors at Oak Ridge National Lab in Tennessee.

"I have been very pleased with Alison's progress towards understanding new quantum magnets synthesized at the Mag Lab," said Wiebe. "Her appointment this summer at another national laboratory will only enhance the broad range of experiences we like to make available to undergraduates at Florida State University." ➔

Students live, learn together

BY SUSAN RAY

Julia Bourg, center, and Kristen Collar, right, have been working with Stan Tozer, left, at the Magnet Lab since their freshman year. *Photo by Ken Ford*

Having the opportunity to work in a national research lab can be a life changing – if not *major* changing – experience for a young woman. Making such opportunities possible is one of the goals of the Women in Math, Science & Engineering (WIMSE) program at The Florida State University. The Mag Lab's Center for Integrating Research and Learning works closely with the program to facilitate the placement of WIMSE students.

FSU's WIMSE students are part of a living-learning community housed at Cawthon Hall. The community brings together first-year students who share an interest in science and take one or more classes together. WIMSE students also participate in colloquiums and other educational and social activities related to their interest in science.

Two of those students started working at the lab their freshmen year. Scholar scientist Stan Tozer of the lab's Extreme Conditions group supports Kristen Collar and Julia Bourg through a grant from the U.S. Department of Energy/National Nuclear Security Administration.

Both young women, who will be juniors in the fall, say their experience at the Magnet Lab has influenced their career paths.

What brought you to the lab?

Kristen: I came to the lab in search of a job. I e-mailed a bunch of scientists from a list that I got from (WIMSE Director Susan Blessing) and then went to visit the lab. I chose the Mag Lab because I loved the atmosphere and enthusiasm of the group.

Julia: Kristen actually brought me to the lab! Kristen and I met our freshman year through WIMSE and she lived down the hall from me in the dorm. She would come back and talk about all the interesting things she was learning, which grabbed my attention initially. I asked Kristen if she thought Dr. Tozer had any space for me in the spring semester (2008) and I've been involved ever since.

Do you think your experience at the Mag Lab will influence your future career path? If yes, how?

Kristen: I know that the Mag Lab has influenced my career path. It led me to participate in the Research Experiences for Undergraduates program at the Mag Lab last summer and the Center for Compact and Efficient Fluid Power REU program at the University of Illinois this summer.

Julia: Definitely. When I started at FSU I was dead set on being a chemical engineer, but working at the lab changed all of that. I just recently changed my major to Biophysics.

What have you learned about what it means to be a scientist?

Kristen: I learned that the challenge of experimental science is patience to keep trying. It seems that things never go right the first time but when it finally works you realize it was all worth it. The daily work at the lab makes me realize how much I have to learn.

Julia: The biggest thing I've learned is how to approach problems when plan A, B, C, etc., have all failed. Especially because there are so many days when it seems that everything goes wrong.

For more information about the WIMSE program,including how to apply, visit http://wimse.fsu.edu.

Has working at the lab influenced your choice of a major or your consideration of graduate school and beyond?

Kristen: I was an Exploratory Sciences, Technology and Engineering major, and after a year of working at the lab, I changed my major to Physics. I have found that I love the challenge of the job and the material I am studying. I am now considering going to graduate school, but still have a lot of thinking to do.

Julia: I changed my major from Chemical Engineering to Biophysics, but I'm not 100 percent sure I want to do that still. I'm really interested in biology, but it's safe to say that I'm going to do something in physics. I also do want to go to graduate school.

Describe your mentor. How has he contributed to your educational and/or personal growth?

Kristen: Stan is full of energy and determination. He is a positive leader and has an endless work list of things for me to do and learn. He has helped me learn everything from fixing ovens, to glove boxes and a flat tire.

Julia: Dr. Tozer has been really incredible. Getting any lab experience as a freshman is really incredible and being able to continue that through my undergraduate education is even better. He's shown me how to be patient and be creative when tackling new problems. ■

A Magnet that Drips: Making Ferrofluids

A ferrofluid is a special liquid with tiny magnetic particles floating around inside. Since these particles are attracted to each other, they must be coated with a special substance that prevents them from sticking together (so that the ferrofluid remains fluid). What makes ferrofluid so special is that in the presence of an outside magnetic field, each of the tiny particles becomes magnetized and the ferrofluid condenses into a solid.

In this activity you will be able to make and play with your own ferrofluid and see how it behaves in the presence of a magnetic field.

What you'll need:

1. Vegetable oil
2. Shallow dish
3. Iron filings
   (from your local hardware store)
4. Napkins
5. A magnet

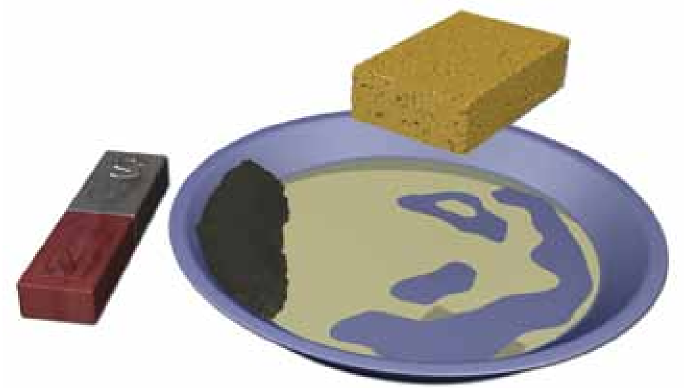
WHAT YOU'LL DO:

1 **Pour a bit of vegetable oil into a shallow dish, just enough to make a thin film across the bottom.**

2 **Pour iron filings into the oil and mix the two until they have become a thick, sludge-like material.**

This is your ferrofluid!

3 Use a napkin or sponge to absorb any excess oil and allow the ferrofluid to become thicker. A good way to do this is to attach a magnet to the outside of the dish. This will solidify the fluid and let you dab away extra oil.



4 Attach a magnet to the bottom of the dish containing the ferrofluid; the fluid will solidify and take the shape of the magnetic field it is in! Removing the magnetic field will allow the ferrofluid to flow like a liquid again.

DID YOU KNOW?

➤ *Ferrofluids are used by the military to coat aircraft; this helps them elude radar.*

➤ *Ferrofluid comes to you courtesy of the same folks who brought you Tang and freeze-dried ice cream: NASA scientists. They came up with the idea in order to confine liquids in space.*

THINK QUICK

WHAT'S ANOTHER WORD FOR MAGNETIZED?

POLARIZED

FERROFIED

IONIZED

➤ *Answer - Polarized! It's a reference to the north and south poles of the magnet. "Ionize" means to turn an atom into an ion by adding or removing an electron. "Ferrofied" isn't actually a word – but it sounds pretty cool, doesn't it?*

Fear not, our nuclear radiation isn't the harmful variety

BY KRISTEN COYNE

Some people are wary of magnetism — maybe because you can't see it. The Mag Lab receives lots of inquiries from people who have concerns about our magnets and what scientists do with them. Magnet Fact or Fiction, a regular *Flux* feature, clears up common misperceptions about the lab.

For example, someone once asked how we protect our employees and people who live near the lab from nuclear radiation. Seems our caller read about our Nuclear Magnetic Resonance program on the Web site. Our response? We do nothing to protect our employees from nuclear radiation.

What's that you say? It's not that we're callous. It's just that NMR (the acronym for nuclear magnetic resonance) produces no radiation – at least not the type of radiation you're probably thinking about.

First of all, not all radiation is created equal. Much of it is considered relatively harmless – the radiation from your television set, for example, or from natural causes such as cosmic rays. Other types can be deadly.

Radiation is all around you. It is associated with particles or waves found both in nature as well as in man-made objects: radio waves, microwaves, X-rays, and visible and ultraviolet light.

These waves are all part of the electromagnetic spectrum. Most waves along this spectrum are relatively low-energy. But higher up the spectrum the particles and waves have more energy – enough to knock the electrons off the atoms and molecules they meet in their paths. This more energetic type is called ionizing radiation, because it ionizes the atoms and molecules (knocks off electrons circling its nuclei), thereby changing them chemically and often resulting in damage (a sunburn, for example, or altered DNA).

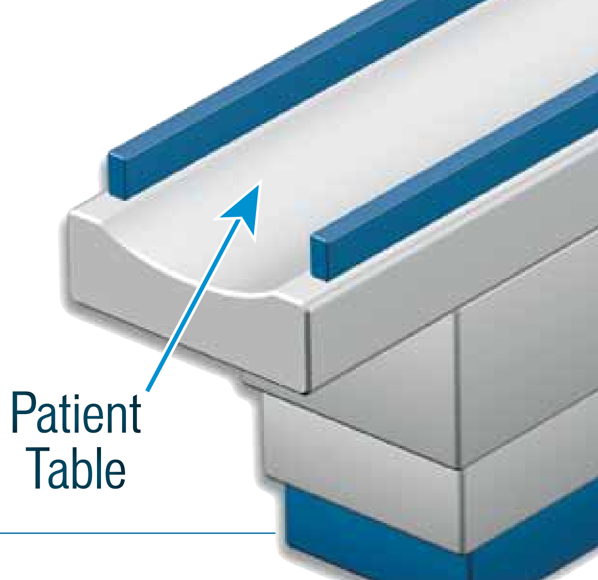
But the type of radiation associated with our NMR machines, and the very powerful magnets that drive them, is non-ionizing radiation – the same stuff that is emitted from your computer and microwave. Unless you are exposed to exceptionally large doses of it, this type of radiation is considered no health threat.

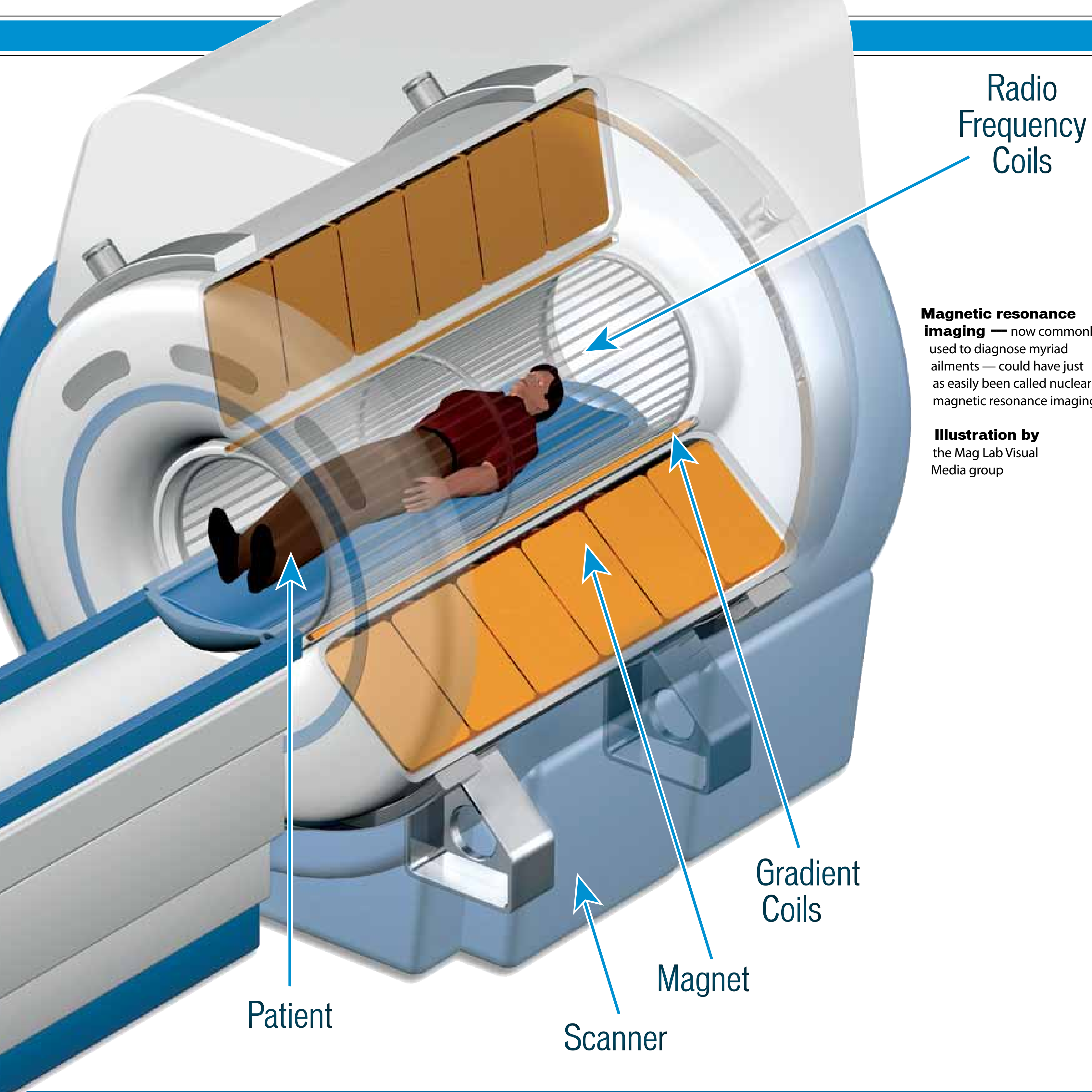
In fact, NMR has a lot more to do with health care than health risks. That's because nuclear magnetic resonance is basically the same thing as magnetic resonance imaging (MRI), a technology that has become a workhorse of diagnostic medicine. But while another diagnostic tool, the X-ray machine, emits ionizing radiation (hence those lead aprons), MRI involves only non-ionizing radiation.

Legend has it that the only reason the medical test is called "MRI" rather than "NMR" is because the general public misunderstands the term "nuclear," often conjuring up images of Nagasaki or Chernobyl. Back in the late 1980s, these were not the images the medical establishment wanted to associate with the promising new technique, so the name was changed to the more innocuous sounding "MRI." ■

WRITE TO US!

➤ *If you have a question — no matter how crazy — you would like an answer to, write us at Flux, 1800 E. Paul Dirac Drive, Tallahassee, FL 32310, or e-mail winters@magnet.fsu.edu with "Fact or Fiction?" in the subject line.*





Magnetic resonance imaging — now commonly used to diagnose myriad ailments — could have just as easily been called nuclear magnetic resonance imaging.

Illustration by the Mag Lab Visual Media group

Discover (or rediscover) the Magnet Lab at public events

FLUX STAFF REPORTS

If you're curious about what goes on inside the National High Magnetic Field Laboratory, you no longer have to wait for the lab's annual Open House to get a peek at our world-record magnets.

This summer, the lab launched standing public tours of the facility. These tours are held on the third Wednesday of each month. No reservations are required – just show up and check in at the reception desk by 11:30 a.m.

Once inside the Magnet Lab, visitors will understand what attracts hundreds of scientists from around the world to Tallahassee to conduct research using custom-made, multimillion-dollar magnets. The tours — which will start at 11:35 a.m. and last about an hour — include a general overview of the lab and the research conducted, as well as explanations of the different types of magnets. Visitors don't even have to skip lunch to take the tour. Soup, sandwiches, salads and more are available at the Starbucks in the lab's atrium lobby.

The monthly tours are intended for individuals and do not replace the group tours the lab has conducted since it opened its doors. The lab continues to offer prescheduled tours for groups of eight or more and special tours for student groups that include a hands-on learning activity. To arrange a group or

What:
Public tours of the Magnet Lab

When:
The third Wednesday of each month

Time:
Tour starts promptly at 11:35 a.m. and lasts about an hour. Because of the size of the building and for other reasons, we cannot allow visitors to be unescorted in the building. Latecomers may not be able to catch up with tours once begun.

A tour guide shows visitors how resistive magnets are made in the lab's Resistive Magnet Shop during a public tour. *Photo by Kristen Coyne* school tour, call Felecia Hancock at (850) 645-0034. For more information about all the lab's tours, visit www.magnet.fsu.edu/tours.

Magnets a mystery no more

To an outsider taking a tour, the Magnet Lab is all glass and steel, instruments flashing, a labyrinth of hallways leading to squat cylindrical magnets organized in cinderblock cells.

Inside these cells — and lots of other places inside the sprawling 370,000-square-foot facility — researchers investigate scientific unknowns, pushing the limits of temperature, magnetic field and mechanical ingenuity to do so. Many visitors leave the lab impressed, a little perplexed, and wanting more.

With that in mind, the lab has organized the Magnet Mystery Hour, an ongoing series of talks that present the lab, its instruments and its research in a way that's accessible to the curious-minded, even if they haven't had a science class since high school (or are currently in high school!). The talks are presented by the scientists themselves — many of them leaders in their fields — in a conversational format appropriate for older students and adults. Each talk is held on a Tuesday night at 7, and is paired with a short tour of the facility at 6:30 p.m. A question and answer session follows each talk. The Magnet Mystery Hour 2009-2010 academic year schedule follows:

Sept. 22, 2009, "The Pull of High-Field Magnets" — Most of the scientists who use the magnets don't work here — and they don't pay us to use the magnets, either. Physicist Eric Palm explains who these "users" are, why they are here, and why it's important to pool national resources to advance fundamental research.

A tour guide shows visitors how resistive magnets are made in the lab's Resistive Magnet Shop during a public tour. *Photo by Kristen Coyne*

Oct. 20, 2009, "Kitchen Table Science For Families" — Bring the kids to this Magnet Mystery Hour to discover science projects adults and children can do together. Center for Integrating Research and Learning Director Pat Dixon introduces "kitchen table science" (or in this case, "conference table science") to participants, who have an opportunity to build their own electromagnets and try other fun and low-cost experiments.

Nov. 17, 2009, "Chemistry of the Underworld" — Ryan Rodgers of the lab's Ion Cyclotron Resonance (ICR) group explains how scientists use very sophisticated tools to simultaneously separate and identify thousands of separate chemical constituents within a single crude oil sample. Dubbed "petroleomics," this new field of research has major implications for how oil companies drill for and refine natural resources.

Jan. 19, 2010, "Magnet Myths and Mysteries" — Physicist Scott Hannahs offers a brief history of electricity and magnetism and discusses some of the most common myths about magnetism and the Mag Lab. He'll take your questions, no matter how strange they might be. If you like good anecdotes, you'll not want to miss this.

March 23, 2010, "Magnets: From Mini to Mighty" — There's a lot more to magnets than you think. This talk features a rundown of magnet types, uses and strengths, explained by Magnet Science and Technology Director Mark Bird in a way that will help make the facts stick. ➔

See art in a science setting

The Magnet Lab's atrium serves as the main entrance for researchers and others visiting the lab, but several times a year, it transforms into Ars Magna, an art gallery and destination for the Council on Culture and Arts' (COCA) First Friday gallery hop.

The goal of Ars Magna ("Great Art" in Latin) is to demystify science and make it more accessible to a different audience. The shows frequently feature artists affiliated with Florida State University or the scientific community, and attract people who wouldn't ordinarily think to visit the Mag Lab. While here, visitors take in the lab's permanent art installation, Magnetic Moment, and have an opportunity to see the lab's big magnets.

All shows are on the first Friday of the scheduled month and are held from 6 to 9 p.m. There is no admission charge. Visitors are welcome to see the art in the lobby during regular business hours (8 a.m. to 5 p.m.), but tours are not available for walk-in visitors.

For a schedule of upcoming shows, visit www.magnet.fsu.edu/arsmagna.

Date set for Open House 2010!

Every February, the Magnet Lab invites the public to spend the day at its world-class research laboratory. Our 2009 Open House attracted a record 5,573 visitors!

Our 2010 Open House is scheduled for Saturday, February 27, 10 a.m. to 3 p.m. This free event features something for young and old alike: hands-on demonstrations, self-guided tours, activities from our Community Classroom Consortium partners, food and the chance to meet and chat with our scientists and other Mag Lab staff. It's also a chance to do good for the community: The canned goods we collect as the unofficial price of admission go to America's Second Harvest Food Bank of the Big Bend.

Open House offers an up-close look at our record-breaking 45-tesla hybrid magnet, our 900-megahertz superconducting magnet and other powerful research instruments. A special Kids Zone features science fun designed especially for young children.

With information and activities targeting a variety of ages, this event has become a popular family outing and is a unique opportunity to show children how fun — yes, fun! — science can be.

For more information on Open House, including and online examples of some of the demonstrations, visit www.magnet.fsu.edu/openhouse.

— Flux staff reports

This piece is just one of a series of permanent artwork at the lab. The installation, called Magnetic Moment, is a symbolic representation of the past, present and future of magnetism and magnet research. *Mag Lab file photo*

Two heads are better than one: the discovery of electromagnetism

BY AMY MAST

Some discoveries are so big that it takes several of an era's best minds working together to achieve them. For example, today, scientists all over the world are working both together and competitively to figure out how and why superconductivity works, and how it can be applied to use energy more efficiently.

Almost 200 years ago, across several countries and without an e-mail inbox in sight, scientists were working this same way to explore the mysterious relationship between electricity and magnetism.

Ørsted: the explorer

If you had some friends over and accidentally made a scientific discovery, you'd probably show it to them and tell them all about it, right?

Not Hans Christian Ørsted of the Netherlands. In the fall of 1820, he invited some colleagues over to show them the way metal could conduct an electrical current. When he fired up the current, he noticed the needle on a nearby compass — on hand for a different demonstration — moved. No one had yet observed a relationship between electricity and magnetism, and Ørsted was stunned. He kept the finding secret for three months while he tried to figure out how and why his demonstration had affected the magnetic field of the compass.

Up until this point, only lodestones (naturally occurring stones with a high concentration of iron) and iron itself were known to give off a magnetic field. Ørsted replicated his finding and studied it intently, but couldn't come up with an explanation for the phenomenon on his own. He ended up publishing his discovery with no explanation.

Ampère: the explainer

The scientific community of the day went crazy trying to explain the phenomenon; over a hundred papers were published on the subject in the following seven years. At the head of the pack was French physicist and mathematics professor Andre-Marie Ampère.

Only a week after he learned of Ørsted's work, Ampère presented his own findings. He demonstrated that when two wires were placed parallel to one another, both carrying an electric current, they'd either be attracted to or repulsed by each other depending on which directions the currents were traveling. If both currents moved in the same direction, the wires would be attracted to one another. If the currents were moving in opposite directions, the wires repelled one another instead.

It sounds simple, but this finding proved the spark for the study of electromagnetism as a field of interest, and became one of the foundations of modern physics. Ampère also figured out how to quantify, or measure, the intensity of the interaction between different electromagnetic currents, and how to nail down the relationship between electricity and magnetism with an equation known as Ampère's Law.

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